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FINAL REPORT
CONTRACT NAS5-21172
FOR
TECHNICAL ENGINEERING SERVICES IN SUPPORT
OF THE NIKE-TOMAHAWK SOUNDING ROCKET VEHICLE SYSTEM

Prepared for:

National Aeronautics and Space Administration
Coddard Space Flight Center
Greenbelt, Maryland 20771

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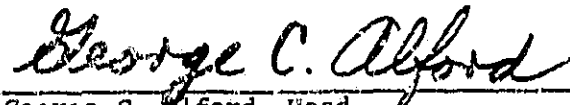
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FOREWORD

Technical and engineering support services provided under contract NAS5-21172 were related to applications involving Nike-Tomahawk sounding rocket systems. Coordination and technical direction for all assignments were provided by Mr. Norman E. Peterson Jr., Head, Solid Propulsion Section, Propulsion Vehicles Branch, NASA/Goddard Space Flight Center.

Thiokol's efforts were principally conducted by the Engineering and Manufacturing Department, Astro-Met Plant, Wasatch Division, located in Ogden, Utah. Contributions to these efforts were directed by Mr. J. F. Strahm, Head, Electronic Systems Section; Mr. P. W. Hoekstra, Head, Aero-Mechanical Systems Section; and Mr. J. D. Lashbrook, Head, Design/Manufacturing Section.



George C. Alford, Head
Engineering and Manufacturing Dept.

SUMMARY

During the contract period from May, 1970 through November, 1972, twelve task assignments were completed by Thiokol Chemical Corporation, Wasatch Division, Astro-Met Plant. As required by Contract NAS5-21172, these assignments, directed by the Sounding Rocket Division, NASA/Goddard Space Flight Center, included technical and engineering services in support of NASA Nike-Tomahawk sounding rocket vehicles.

Task assignments were completed in the following work areas:

- a) Analytical Services - Extrapolation of Nike-Tomahawk trajectories based on radar data obtained during the early portion of flight and preparation of wind weighting and impact prediction charts for field service assignments.
- b) Design and Drafting Services - Design and preparation of drawings for a payload-to-Tomahawk mechanical attachment joint with improved elastic properties, for a RAG launcher umbilical boom, and for a nose cone thermal test model.
- c) Fabrication and Modification Services - Fabrication and/or modification of Tomahawk tail assemblies for special applications requiring fin area larger than standard, of Tomahawk firing and despin module to satisfy requirements for a specific payload, of a RAG launcher umbilical boom, and of various test models and fixtures.

- d) Field Engineering Services — Assembly and checkout of Nike-Tomahawk sounding rocket vehicles at launch sites including Poker Flat Rocket Launching Facility near Fairbanks, Alaska, and the San Marco Equatorial Range near Malindi, Kenya.

Depending on the type of assignment, the effort on a task was terminated by delivery of data or an analysis report, by delivery of new or modified components, or by the launch of the Nike-Tomahawk vehicle.

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INTRODUCTION

This report was prepared for the Goddard Space Flight Center of the National Aeronautics and Space Administration by the Astro-Met Plant, Wasatch Division of Thiokol Chemical Corporation as a final report on Contract NAS5-21172. Descriptions of technical and engineering support task assignments completed under this contract are given in the following sections.

Activities conducted in this program were related to various aspects of research programs using the NASA Nike-Tomahawk sounding rocket vehicle. The NASA Nike-Tomahawk has been a reliable rocket system for carrying scientific payloads for research in the upper atmosphere since NASA/GSFC began to use this two-stage vehicle in 1965. As a supplier of major components for the Nike-Tomahawk vehicle throughout its development and subsequent production, Astro-Met personnel are familiar with all aspects of using this sounding rocket system. This experience was valuable in completing the task assignments on the current program which included effort in the areas of:

- a) Analytical Services
- b) Design and Drafting Services
- c) Fabrication and Modification Services
- d) Field Engineering Services.

ASSIGNMENT NO. 1

Purpose: Compute a flight trajectory for NASA 18.91 UE Nike-Tomahawk vehicle based on radar data obtained during the early portion of the flight.

In order to reduce sounding rocket payload data, the experimenter often requires information regarding the trajectory of the vehicle. This, however, is not always readily available when launchings are made from Fort Churchill, Canada. This problem is circumvented by performing a radar data reduction consisting, primarily, of a computer extrapolation of available radar data. This extrapolation consists of fitting a computed trajectory to the radar data, and assuming nominal vehicle characteristics throughout the remainder of the flight. This approach is highly reliable since the radar data drop-out normally occurs after second-stage burnout, therefore, the remaining trajectory is thus a pure ballistics problem.

A complete trajectory for the NASA 18.91 UE Nike-Tomahawk vehicle was derived by correlating computed trajectories with Fort Churchill radar data. The radar data was continuous up to a flight time of almost 200 seconds. Both motor impulse and launch elevation angle (effective) were considered independent variables. The results of this analysis show vehicle performance to be very near nominal in terms of motor performance, but having an effective launch angle of 85.3 degrees. This resulted in an apogee altitude of 873,531.1 feet at 253.1 seconds after launch, with impact occurring at a range of 384,092 feet at a flight time of 496.57 seconds. Although motor impulse was considered a variable, the results of this study indicated nominal motor performance.

ASSIGNMENT NO. 2

Purpose: Fabricate an umbilical boom for a RAG launcher.

NASA/GSFC uses a Thiokol RAG launcher in research programs involving Nike-Tomahawk vehicles launched from remote sites. The RAG launcher and its mounting base are transported by air to the launch site along with the rocket motors and other equipment. Several successful programs have been conducted in high northern latitude locations using this launcher at a temporary installation.

An umbilical boom was required for attachment to the RAG launcher. The boom structure would provide support for checkout and control cables routed from the launch control center to the vehicle payload. Fly-away connectors on the umbilical cables were rigged to allow the cables to disconnect automatically as the vehicle left the launcher.

Design criteria for the umbilical boom included requirements based on previous experience in operating from temporary northern latitude sites. These criteria included:

- a. Minimum boom deflection in 40 knot winds or as a result of launch dynamics.
- b. Minimize boom weight and manufacture in segments to ease shipping problems.
- c. Length of boom sufficient to reach payload region of a Nike-Tomahawk vehicle.
- d. Base of boom configured to mount on elevation arm of RAG launcher.

- e. Umbilical boom height above vehicle center line sufficient to assure no collisions with vehicle, but not so high as to cause interference with removable assembly shed planned for vehicle protection.

An umbilical boom was fabricated as a welded tubular steel tapered truss which satisfactorily met these criteria. The boom was used during the launch of Nike-Tomahawk vehicles NASA 18.122 GE; 18.123 GE; 18.124 GE; 18.125 GE; 18.126 GE; 18.127 GE; 18.128 GE; and 18.129 GE from the Fox Main DEW line site in March, 1971.

ASSIGNMENT NO. 3

Purpose: Refurbish one Tomahawk firing and despin module.

A Tomahawk firing and despin module (FDM) which had been used in testing by NASA/GSFC was returned to Thiokol/Astro-Met for refurbishment. The FDM was disassembled, inspected and new parts were made as required. Following assembly and checkout, the FDM (P/N R-00400-10) was returned to NASA/GSFC.

ASSIGNMENT NO. 4

Purpose: Fabricate two Tomahawk tail assemblies with fin area larger than NASA's standard design.

The standard NASA/GSFC Tomahawk tail assembly has an area of 207 square inches for each fin and has a leading edge swept at 45 degrees. For special applications a larger fin area is sometimes desirable. An alternate flight-proven Tomahawk tail assembly uses fins swept at 55 degrees with an area of 266 square inches. While the larger tail assembly is heavier, this is largely offset by the lower drag associated with the more swept design. The 266 square inch fin blade has an asbestos phenolic leading edge for thermal protection rather than the stainless steel cuff used on the standard fin.

Two tail assemblies with 266 square inch fins fabricated on this assignment were intended for flight on a Nike-Tomahawk vehicle to be launched by the Space Technology Group, Swedish Space Research Committee. This application involved the launch of a bulbous payload, 12 inches in diameter, with a length of 141 inches. Payload weight was 286 pounds.

Considerable analyses of the vehicle flight dynamics led to the selection of a roll profile which required a fin incidence angle of 34 minutes. The fins were set to 34 minutes before shipment.

Subsequent studies by the user produced a decision to increase the fin incidence to 37 minutes which was accomplished by a field adjustment. One of the tail assemblies, with 37 minute fin incidence was flown on vehicle 18.131 IA in February, 1972. Vehicle and payload performance were nominal, but impact was beyond range limits. This undesirable impact point may be a result of the difficulty in properly wind weighting a vehicle launched at near vertical, 88 degrees, launch elevation angles.

ASSIGNMENT NO. 5

Purpose: Modify one Firing and Despin Module to include a new battery pack.

A Tomahawk Firing and Despin Module (FDM), R-01360-1, was returned for modification to incorporate a sealed, squib-activated battery pack. The new battery pack was an Eagle-Pitcher Model GAP-4147-3. Included in the battery pack are heating elements and activation squibs. Both the heating circuit and the squib firing circuit were wired through the FDM umbilical to provide control from the launcher blockhouse. During the final countdown electrolyte is released and the battery activated by firing its internal squibs. The battery is sealed to prevent out-gassing.

In addition to the flight battery pack, three spare batteries were supplied. The modified FDM was wired per schematic D-01738 and the necessary mounting brackets and special connectors were fabricated and installed.

ASSIGNMENT NO. 6

Purpose: Fabricate four (4) Tomahawk tail assemblies with a fin area of 266 square inches per fin blade.

Four Tomahawk tail assemblies, R-00527-3, were fabricated, assembled and delivered for use with NASA Nike-Tomahawk vehicles requiring larger fin area than the standard NASA tail assembly. As discussed for Assignment No. 4, each fin blade has a planform of 266 square inches.

A fin incidence of 22 minutes was preset for these tail assemblies prior to shipment.

ASSIGNMENT NO. 7

Purpose: Provide Field Engineering Services for a Nike-Tomahawk launch from the San Marco Equatorial Launch Range.

A Thiokol vehicle engineer accompanied the NASA Vehicle Systems Manager during a launch program conducted at the San Marco Equatorial Launch Range. Nike-Tomahawk NASA 18.103 GA was launched from the San Marco Platform near Malindi, Kenya at 08:33:54, 17 November 1971, local time.

The vehicle carried a payload weighing 143 pounds which was 81.4 inches in length. In addition to telemetry and the standard Tomahawk Firing and Despin Module, the thermosphere probe payload carried an omegatron mass spectrometer, an electrostatic probe, and an aspect sensor. A special nose cone design was incorporated to allow ejection of the thermosphere probe.

A Nike-Ajax launcher was used to launch the vehicle at an elevation angle of 77.3 degrees and an azimuth of 65 degrees. Flight parameters for the vehicle were near nominal.

ASSIGNMENT NO. 8

Purpose: Provide Field Support Services during Nike-Tomahawk launches at the Poker Flat Rocket Launching Facility.

Thiokol provided a field service engineer to assist the NASA/GSFC Vehicle Coordinator during two Nike-Tomahawk launches from the Poker Flat Facility near Fairbanks, Alaska. The first vehicle, NASA 18.111 UE, was launched on 2 February 1972 and the second, NASA 18.112 UE, was launched on 24 February 1972.

Payload weight for these vehicles was 210 pounds and payload length was 119.6 inches. The Tomahawk firing circuit was removed from a FDM and installed in the aft section of the payload along with the radar beacon and VHF telemetry. Instrumentation aboard the payloads measured magnetic fields and particle fluxes during the flight. A standard Tomahawk ceramic nose cone was employed. Special tension joints used in the payload had a maximum outside diameter of 9.25 inches.

Both vehicles were launched from the MRL 7.5 K launcher. NASA 18.111 UE was launched with launcher settings of 72.0 degrees elevation and 25.9 degrees azimuth while NASA 18.112 UE settings were 73.3 degrees elevation and 28.6 degrees azimuth. Effective elevation and azimuth for both flights were 71 degrees and 29 degrees. Flight trajectories for both vehicles were reported as nominal.

ASSIGNMENT NO. 9

Purpose: Prepare preliminary design drawings for a Tomahawk-to-FDM interface.

A preliminary design was completed and drawings issued to define a tension joint interface for the Tomahawk head cap and the mating FDM. Sketches were prepared for: 1) Tomahawk Head Cap G-SK-00160, 2) FDM G-SK-00161, and 3) Payload Tension Joint D-SK-00159.

The design failure moment for the proposed tension joint was 200,000 inch-pounds and the design was limited to configurations which could use existing Tomahawk head cap forgings. As proposed, the tension joint utilizes twenty four (24) socket head cap screws 1/4-28 UNF-3A x 5/8 inch long to attach the FDM or payload section to the Tomahawk head cap. Screws are inserted in a forward direction through clearance holes drilled in the head cap at an angle of 30 degrees to the longitudinal axis of the motor. Mating parts would be drilled and tapped to accept the screws installed at the 30 degree angle.

After consultation with technical personnel of NASA/GSFC Propulsion Vehicles Branch the proposed design with minor modifications was used in a successful test program (Assignment No. 11) and eventually evolved to become a new standard interface configuration for the Tomahawk motor.

ASSIGNMENT NO. 10

Purpose: Provide Field Service Support for preparation and launch of three Nike-Tomahawk vehicles carrying chemical release payloads.

Three Thiokol field service personnel participated in a launch program from the Poker Flat Rocket Launching Facility near Fairbanks, Alaska during the period from 21 February through 10 March 1972. Three Nike-Tomahawk vehicles launched during this period carried Thiokol's chemical release payloads each of which released four individual barium/strontium vapor clouds and a TMA trail along its flight trajectory.

In addition to the usual preparation, assembly, checkout and loading of the Nike-Tomahawk vehicles, the program also required installation, alignment and operation of a RAG launcher which was used in the program.

Upper stage firing circuitry was provided through a modified FDM. The modification included installation of battery heaters and thermistors to monitor battery temperature. The FDM battery pack was also used to power payload functions after Tomahawk burnout. Each payload weighed 141 pounds and had a length of 81.6 inches. A 3:1 tangent ogive nose cone fabricated of asbestos phenolic was used.

NASA 18.141 GE was launched at 05:16:00; 7 March 1972 (UT). NASA 18.142 GE was launched at 14:26:00; 7 March 1972 (UT). NASA 18.143 GE was launched at 14:08:00; 9 March 1972 (UT). All three vehicles were launched at an effective elevation angle of 80 degrees and an effective azimuth angle of 20 degrees. Flight trajectories appeared nominal in all cases.

ASSIGNMENT NO. 11

Purpose: Fabricate a test unit and tooling for a Tomahawk tension joint.

A tension joint test unit was designed and fabricated to simulate the Tomahawk head cap and the mating FDM housing proposed in the interface design developed during Assignment No. 9. The fabrication effort included manufacturing a drill fixture which would insure proper alignment of the test parts.

The test unit was delivered to NASA/GSFC for testing with the following results reported by personnel in the Propulsion Vehicles Branch.

A three cycle reversing bend test was conducted using the simulated motor head cap, P/N C-SK-00160, and the simulated FDM housing, P/N C-SK-00161. Joint rotation measurements taken at the joint between the two parts yielded a joint stiffness coefficient of 2.43×10^{-9} radians/inch-pound with no slip. This coefficient was repeatable when tested at $\pm 60,000$ inch-pounds and appeared to also apply for moments of $\pm 81,000$ inch-pounds. The joint exhibited elastic behavior throughout these tests. The test moment of 81,000 inch-pounds was derived from predicted moments for a Nike-Tomahawk vehicle carrying a 120 inch payload weighing 100 pounds subjected to a 3 degree angle of attack at maximum dynamic pressure during Nike burn.

A design essentially identical to that tested has subsequently been adopted as the standard interface configuration for the Tomahawk motor. Tomahawk motors employing the new head cap design are identified as P/N E15209-25 (anodized) or P/N E15209-26 (unanodized).

ASSIGNMENT NO. 12

Purpose: Modify and instrument a Tomahawk Nonmetallic Nose Cone for thermal simulation tests.

The forward 14 inches of a Tomahawk asbestos phenolic nose cone, P/N R-01731, was modified and instrumented for a thermal simulation test performed in the NASA/Ames Arc-Heated Planetary Gas Wind Tunnel. The test was to substantiate the thermal adequacy of the nose cone by subjecting it to a thermal pulse which approximated that experienced due to aerodynamic heating in a "worst case" trajectory. A trajectory for a Nike-Tomahawk carrying a 60 pound payload launched at an elevation angle of 75 degrees was selected to derive the aerodynamic heating pulse.

Test conditions matched the peak stagnation heat transfer rate expected in flight; however, the heat transfer rate on the ogive downstream of the stagnation point was not the same as expected in flight since pressures and Reynolds number in the test section could not reach the flight values.

From the test results, the stagnation region appears to have adequate ablative material to survive the anticipated heat pulse. Although the maximum internal surface temperatures, 180° F, did not reach predicted flight values, flight temperatures are expected to be somewhat higher than the test values since turbulent boundary layer conditions will exist in flight. The asbestos phenolic nose cone should perform satisfactorily in flight on Nike-Tomahawk vehicles.